Solenoid-Activated Metering Device for the Continuous Dispensing of Liquid Growth Medium

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SOLENOID-ACTIVATED METERING DEVICE FOR THE CONTINUOUS DISPENSING OF LIQUID GROWTH MEDIUM

by

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ABSTRACT

Hendzel, L.L. 1986. Solenoid-activated metering device for the continuous dispensing of liquid growth medium. Can. Tech. Rep. Fish. Aquat. Sci. 1489: iv + 8 p.

The construction of an electronically controlled, electro-magnetic metering device for the timed delivery of liquid growth medium is presented. The apparatus consists of two parts, each assembled from readily available components. These are a timing module and a solenoid activated gate. Silicone tubing, passing through the gate; connects the pressurized medium reservoirs to the culture vessels. Performance data is presented for one particular application.

Key words: solenoid; interval timer-relay; metering; liquid growth medium; semi-continuous cultures; algae.

RÉSUMÉ

Hendzel, L.L. 1986. Solenoid-activated metering device for the continuous dispensing of liquid growth medium. Can. Tech. Rep. Fish. Aquat. Sci. 1489: iv + 8 p.

On décrit la construction d'un appareil électromagnétique électronique servant à mesurer le débit d'un milieu de culture liquide. L'appareil est constitué de deux parties, soit un chronomètre et une vanne actionée par un solénoide, qu'on peut assembler à l'aide de pièces faciles à trouver. Une canalisation en silicone qui traverse la vanne joint les réservoirs pressurisés de milieux de culture et les récipients de culture. On présente des données sur le rendement d'une expérience menée à l'aide de cet appareil.

Mots-clés: solénoide; relais pour chronomètre; mesure; milieu de culture liquide; cultures semi-continues; algue.

INTRODUCTION

The need for an inexpensive and reliable way of controlling the flow of liquid medium to a number of semi-continuous algal cultures resulted in the development of a device which would repetitively and accurately control the aseptic delivery of medium from pressurized reservoirs, through silicone tubing to algal cultures. The relatively low cost of this device made practical the use of many such cultures for growth-related experiments. Commercially-avialable peristaltic pumps would provide the controlled flow needed but were too expensive for the number of cultures required. Less costly methods of medium delivery to semi-continuous cultures were explored.

Initially, manually-controlled, semi-continuous cultures were used. In this procedure, a volume of culture is aseptically removed by pipette daily and an equal volume of sterile medium added. This single daily addition of fresh medium results in large fluctuations in the concentration of limiting nutrient, which can have an effect on the outcome of the competition experiment (Turpin and Harrison 1979). The use of gravity flow from flasks and Mariotte bottles, controlled by metering valves was unsuccessful. At the low flow rates needed (10 mL per 24 h), uniform control of these devices was very difficult. Finally, a gate valve activated by a solenoid was developed where the flow of liquid medium through silicone tubing from pressurized reservoirs was controlled by periodic opening of the gate for short intervals.

METHODS-APPARATUS

The dispensing controller consists of two parts (Fig. 1), the timing module and the solenoid-activated gate, connected by a length of two-conductor wire. The timing module provides a range of "off" times with one set "on" interval. A rotary switch is used to select one of 10 "off" intervals ranging from 10 to 300 s. This "off" interval is the length of time that the solenoid is non-energized, with the gate being firmly pressed against the silicone tubing preventing any flow of medium. After the elapse of the selected "off" time interval, the solenoid is energized for a fraction of a second (<0.1 s), retracting the gate, allowing a pulse of medium to flow through the silicone tubing.

The timing module has three separate relays (Fig. 2): a timing relay (RL-1) which controls the length of time the solenoid gate remains non-energized, an intermediate DC relay circuit (RL-2) which lengthens the time of the "on" cycle of the solenoid gate, and a solid-state (opto-isolated) relay (RL-3) to switch the high inductive load of the solenoid. Control voltages to relays RL-1 and RL-3 is 120VAC, and 110VDC to RL-2, while all relays switch 120VAC. Figure 2 illustrates the timing and switching circuit. Line current (120VAC) passes through a 2.5-amp slow-blow fuse and branches into two routes, one directly to terminal 1 on the output side of RL-3 (Crydom A1210, International Rectifier) and the other through the normally closed contacts of relay RL-2 (KRP-5DG, AMF-Potter and Brumfield) to the input of the time delay relay RL-1 (R15A-300A-15-X4E1, AMF-Potter and Brumfield). The time delay function is controlled by 11 resistors (R3-R13). These are arranged in series around a 10-position rotary switch, SW-1, (Centralab PA2001), and controls the length of time the output contacts of relay RL-1 remain open. When the selected time interval has elapsed, the contacts of timing relay RL-1 close, energizing the intermediate relay (RL-2) circuit through a full-wave bridge rectifier (W-1) charging capacitor C-1 (8 µF, 250VAC electrolytic) and closing the contacts of relay RL-2 which energizes the input side of RL-3 through terminal 4, resulting in activation of the solenoid. The contacts of the timing relay RL-1 open and capacitor C-1 discharges. After discharge, the contacts of the intermediate relay RL-2 return to their normally closed position, removing power to the solenoid, which in turn switches power back to the timing relay RL-1, restarting the cycle. The length of this "on" cycle is determined by the value of capacitor C-1; a higher capacitance will result in the solenoid being energized for a longer period. Resistor R-1 (1.2 KΩ, 1/2 watt) protects the bridge rectifier (W-1) while resistor R-2 (4.7 KΩ, 1 watt) protects the intermediate relay RL-2. Resistors R3 to R13 (see parts list for resistance values) are selected in accordance with the specifications of the timing relay RL-1. Component specifications may vary depending on the application.

All components were wired using point-to-point connections within a suitable metal enclosure. The timing relay RL-1 and the intermediate relay RL-2 were mounted in the appropriate sockets while the solid-state relay RL-3 was mounted directly to the enclosure. Two three-lug terminal strips were used to simplify mounting of the rectifier W-1 and associated resistors R-1, R-2 and capacitor C-1. Output from the solid-state relay was connected to an enclosure-mounted, two-pin Jones socket (S-302-AB).

The design of the timing module circuit was altered slightly in order to simplify construction. The changes involved (Fig. 2a) replacing the P&B timer relay (R15A-300A, 115VAC X4E1) and the rotary switch with its array of resistors with an Agastat solid-state time-delay relay (Amerace Ltd., Markham, ON; model SSC 22AGA). Also the intermediate switching relay (RL-2) was replaced with a 110VDC double pole, double throw relay (P&G KRP 11DG) to energize RL-3 and secondly, to provide the necessary feedback to reset the timer in RL-1. This modification offered the same range of "off" times, without affecting reliability or the cost.

The solenoid-powered gate was constructed of easily obtainable materials and simply bolted together. The base was constructed of a piece of "U-shaped" channel iron (18 cm long x 12 cm high). Bolted to the base were two "L-shaped:" side brackets, (20 cm long x 5 cm wide with a 90° bend approximately 4 cm from one end) spaced 7.5 cm apart. The solenoid (Guardian pull type 18 intermittent duty, 120VAC) was mounted at the

top, equidistant between the two L-brackets. A block of plastic on one side of the solenoid was necessary for proper spacing. A steel rod (80 mm long x 8 mm diameter) passed through a hole in an aluminum block and connected the solenoid plunger to the centre of a steel bar (70 mm long x 13 mm wide x 6 mm thick) perpendicular to the steel rod. The bottom edge of the bar was ground to the shape of a blunted vee. The length of the rod must allow for approximately 5 mm of travel when the solenoid is energized. The aluminum guide block (78 mm long x 38 mm wide x 25 mm thick), mounted directly beneath the solenoid acts to center the rod. This keeps the gate mechanism perpendicular to the base and acts as a bearing point for one end of a compression spring which holds the gate firmly against the base when the solenoid is not energized. The spring chosen was 25 mm long x 10 mm diameter and required 5-7 kg of pressure for 50% compression. The spring must be able to exert enough force to keep the silicone tubing pinched closed but not too stiff to prevent the solenoid from raising the vee bar clear of the tubing when energized. The solenoid powered gate can be semi-enclosed with an aluminum box. When left uncovered, it was easy to raise the gate manually in order to position the silicone tubes between the vee-bar and the base. A piece of thin rubber (1.0 mm thick) on the base cushioned the impact of the vee bar when the solenoid cycled on and off. Silicone tubes were held in place on either side of the gate by a two-piece plexiglass block, each half having semi-circular notches in which the tubes were placed. The corresponding top half was placed over the lower half and held in place with screws. When the silicone tubing shows signs of wear, another section can be drawn into place.

Each semi-continuous culture consisted of a sealed, pressurized medium reservoir connected to a non-sealed culture flask by a length of silicone tubing (Fig. 3). The medium reservoirs were 500 mL Erlenmeyer flasks, filled with 400 mL of sterile inorganic medium. The top of each medium reservoir was sealed with a #7 green neoprene stopper through which passed one long glass tube extending to the bottom of the flask, and one short length of glass tubing extending just below the bottom of the stopper. A suitable length of silicone tubing was fastened to the long glass tube and routed through the solenoid-activated gate to the appropriate culture flask. The other glass fitting allowed for pressurization with sterile air at a constant pressure of 0.035 $kg \cdot cm^{-2}$. The silicone tubing used between the medium reservoir and the culture flask was a thin-walled type (Cole-Parmer 6411-62, Cole-Parmer Instrument Co., 7425 North Park Avenue, Chicago, Illinois) which allowed for positive sealing by the vee bar but also afforded good elastic memory. The culture vessels were 125 mL Erlenmeyer flasks stoppered with gauze-wrapped sterile cotton, through which passed the silicone tubing from the medium reservoir to a point just below the stopper. A length of glass tubing, extending to the bottom of the culture flask, was connected by silicone tubing to a serum stoppered test tube, allowing for daily sampling.

DISCUSSION

Performance was monitored over a 16 day period (Table 1), at one "off" time interval setting; that is, one dilution rate. The average volume dispensed per 24 h was 16.1 mL with the range being 15.1-17.8 mL per 24 h. Long term experiments (up to 30 days) requiring the delivery of small volumes of medium (10 mL per 24 h) have been repeated many times, proving the device to be reliable and durable. At a constant reservoir pressure of 0.035 $kg \cdot cm^{-2}$, the volume dispensed can be varied from 0.65 $mL \cdot h^{-1}$ to 24 $mL \cdot h^{-1}$. Additional flexibility in selecting the length of time cycles and regimes can be easily attained by plugging the unit into an inexpensive programmable timer.

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Table 1. Volume of distilled water dispensed per 24 hours over 16 days at 20° C with a reservoir pressure of 0.035 $kg \cdot cm^{-2}$.

Day	$mL \cdot 24\ h^{-1}$	Day	$mL \cdot 24\ h^{-1}$
1	16.1	9	16.8
2	17.3	10	16.3
3	17.0	11	15.3
4	15.1	12	15.5
5	17.8	13	15.4
6	16.2	14	15.2
7	16.0	15	15.3
8	16.5	16	16.5

Table 2. List of parts.

Resistors	**Intermediate Switching Relay**
R-1 - 1.2 KΩ 1/2 watt	P&B KRP-5DG
R-2 - 4.7 KΩ 1 watt	120VCD input 120 VAC output
R-3 - 47 KΩ 1/2 watt	
R-4 - 56 KΩ 1/2 watt	**Solid State Relay**
R-5 - 100 KΩ 1/2 watt	
R-6 - 180 KΩ 1/2 watt	Crydom A1210
R-7 - 220 KΩ 1/2 watt	International Rectifier
R-8 - 220 KΩ 1/2 watt	120VAC input and output
R-9 - 220 KΩ 1/2 watt	
R-10 - 150 KΩ 1/2 watt	**Rotary Switch**
R-11 - 120 KΩ 1/2 watt	
R-12 - 120 KΩ 1/2 watt	Centralab #PA2001
R-13 - 100 KΩ 1/2 watt	Ten position rotary switch
Capacitor	**Solenoid**
C-1 - 8uF250 VDC	Guardian pull type #18 intermittent duty 120VAC
Rectifier	**Misc. Hardware**
Full-wave bridged 1.5 A, P.I.V. = 200	Wire Spade lugs Terminal strips Jones plug and socket Metal enclosure Power cord Knob for rotary switch Misc. screws, nuts, washers, etc.
Fuse Holder	
Littlefuse	
Fuse	
Littlefuse 2.5 A Slow Blow	**(As per modification)**
Timer-Relay	Agastat relay SSC 22AGA P&B KRP 11DG 110VDC input 120VAC output
P&B R15A-300A 115VAC X4E1	

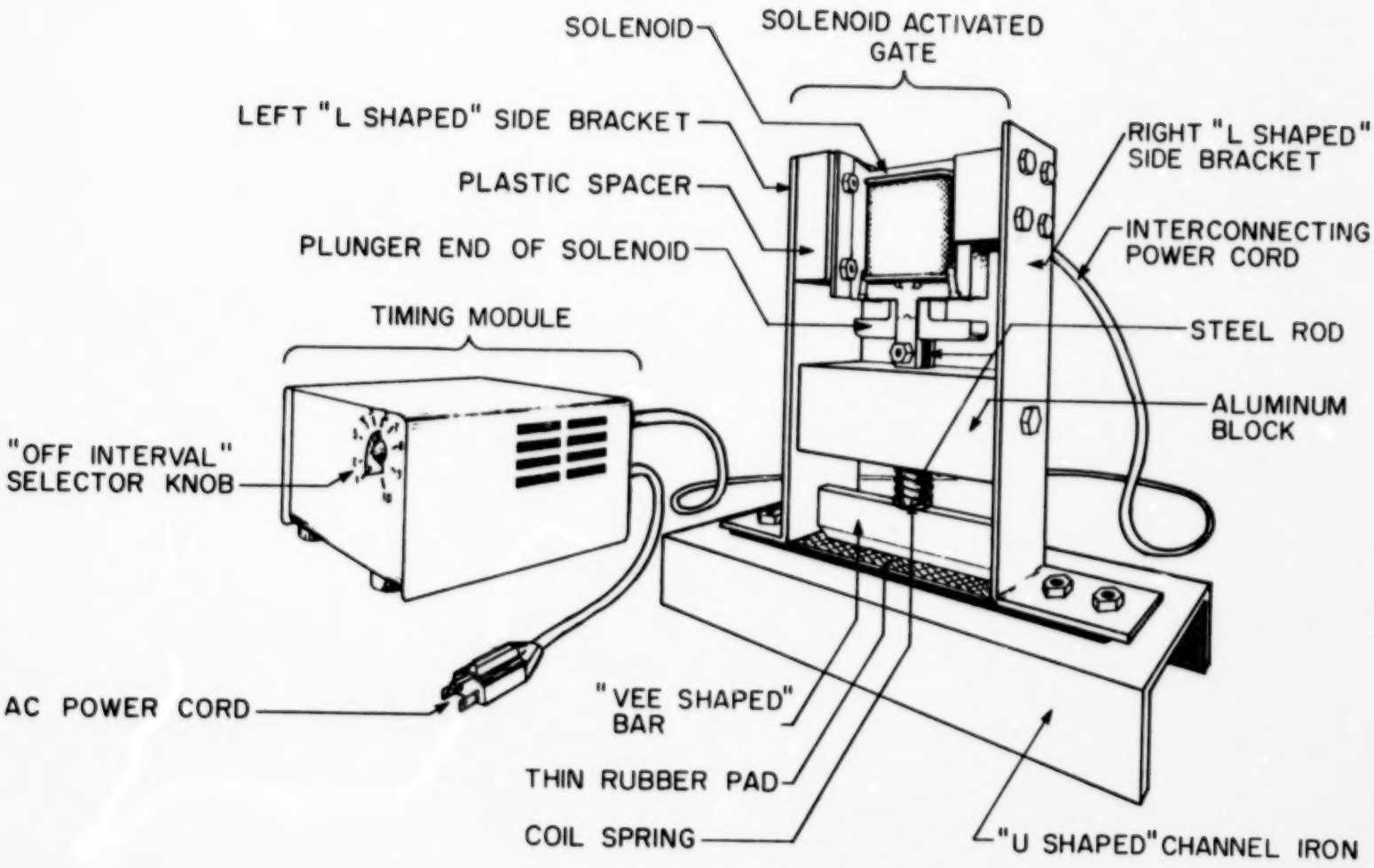

Figure 1. Diagram of the two components of the dispenser: the timing module and the solenoid activated gate

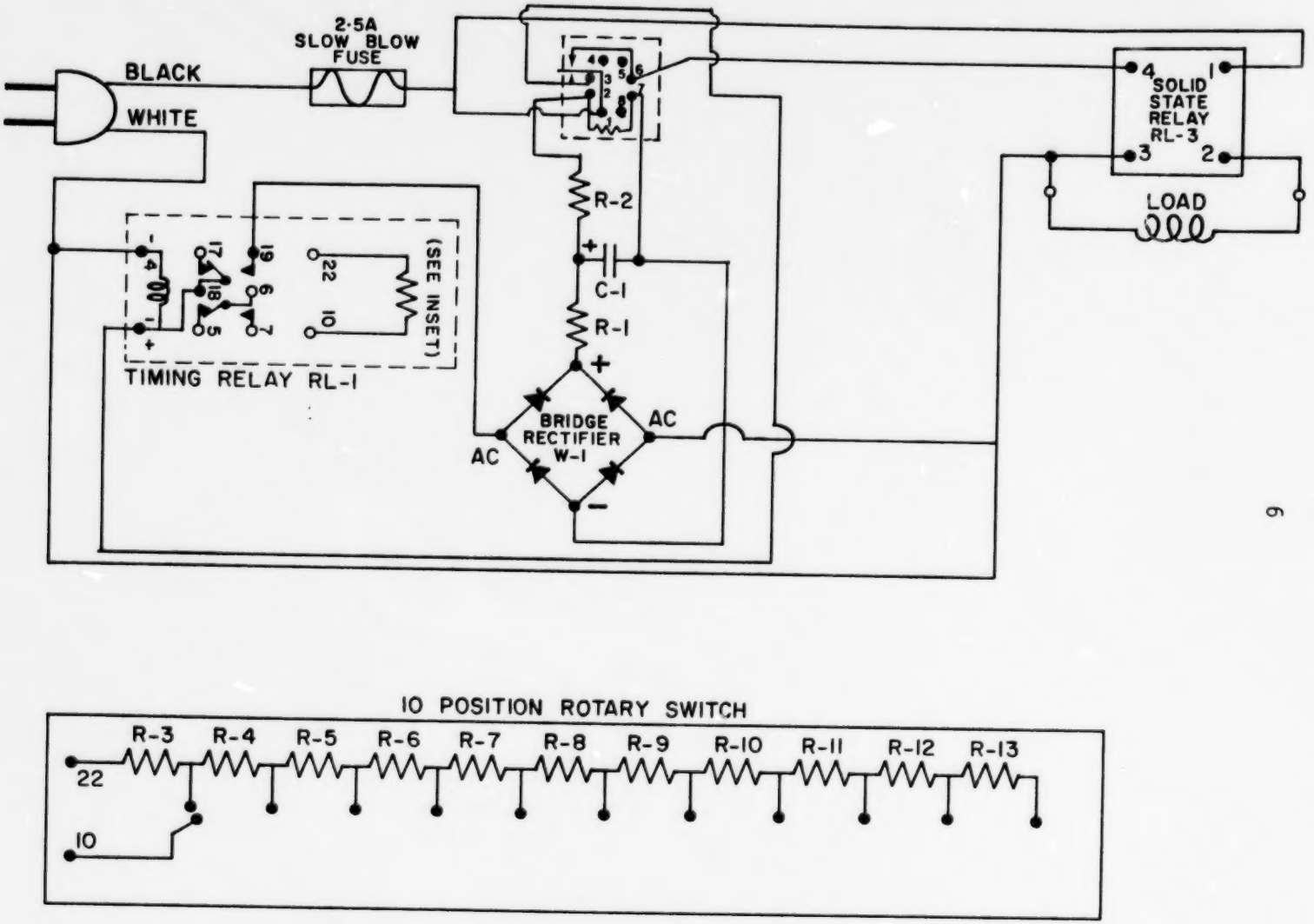

Figure 2. Schematic diagram of the timing module circuit.

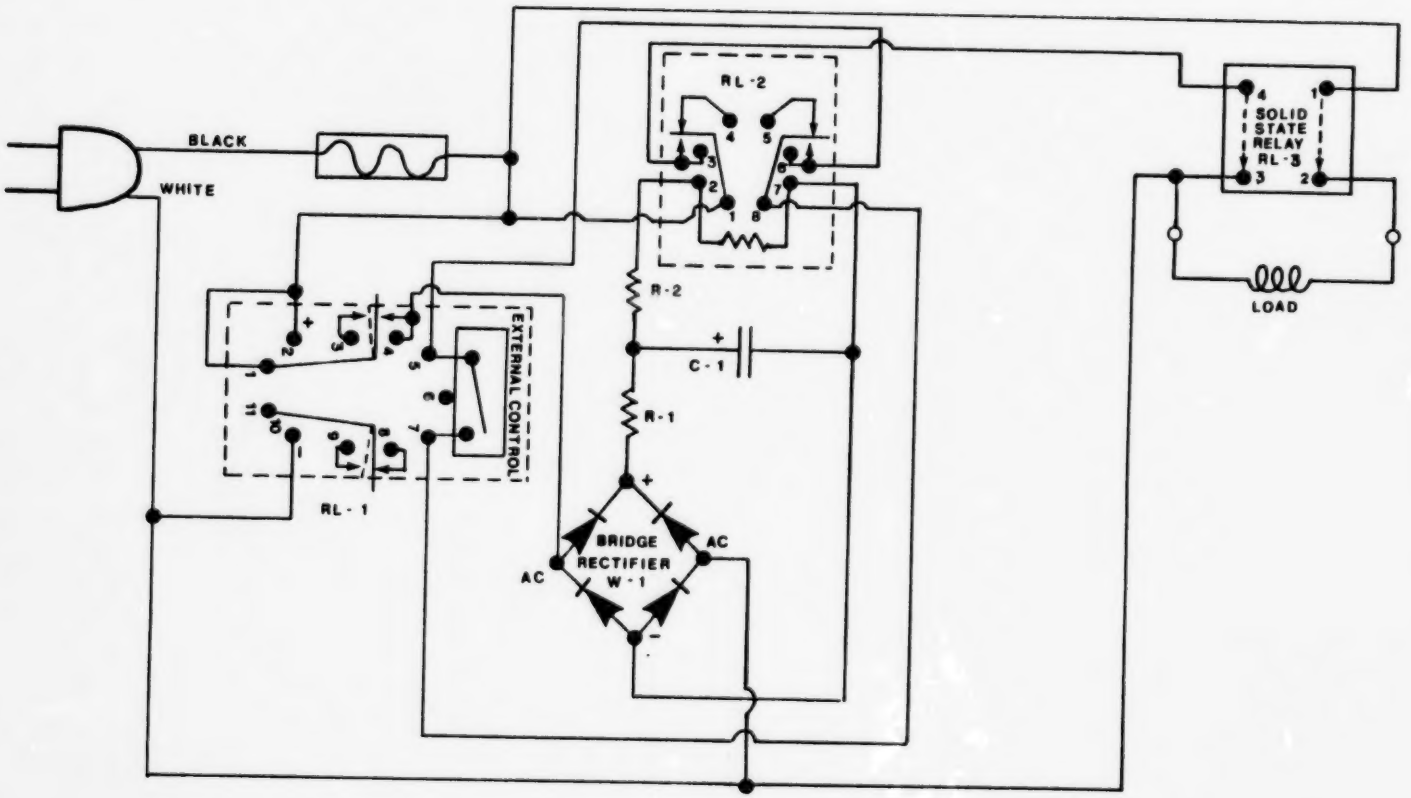

Figure 2a. Schematic diagram of the modified timing module circuit.

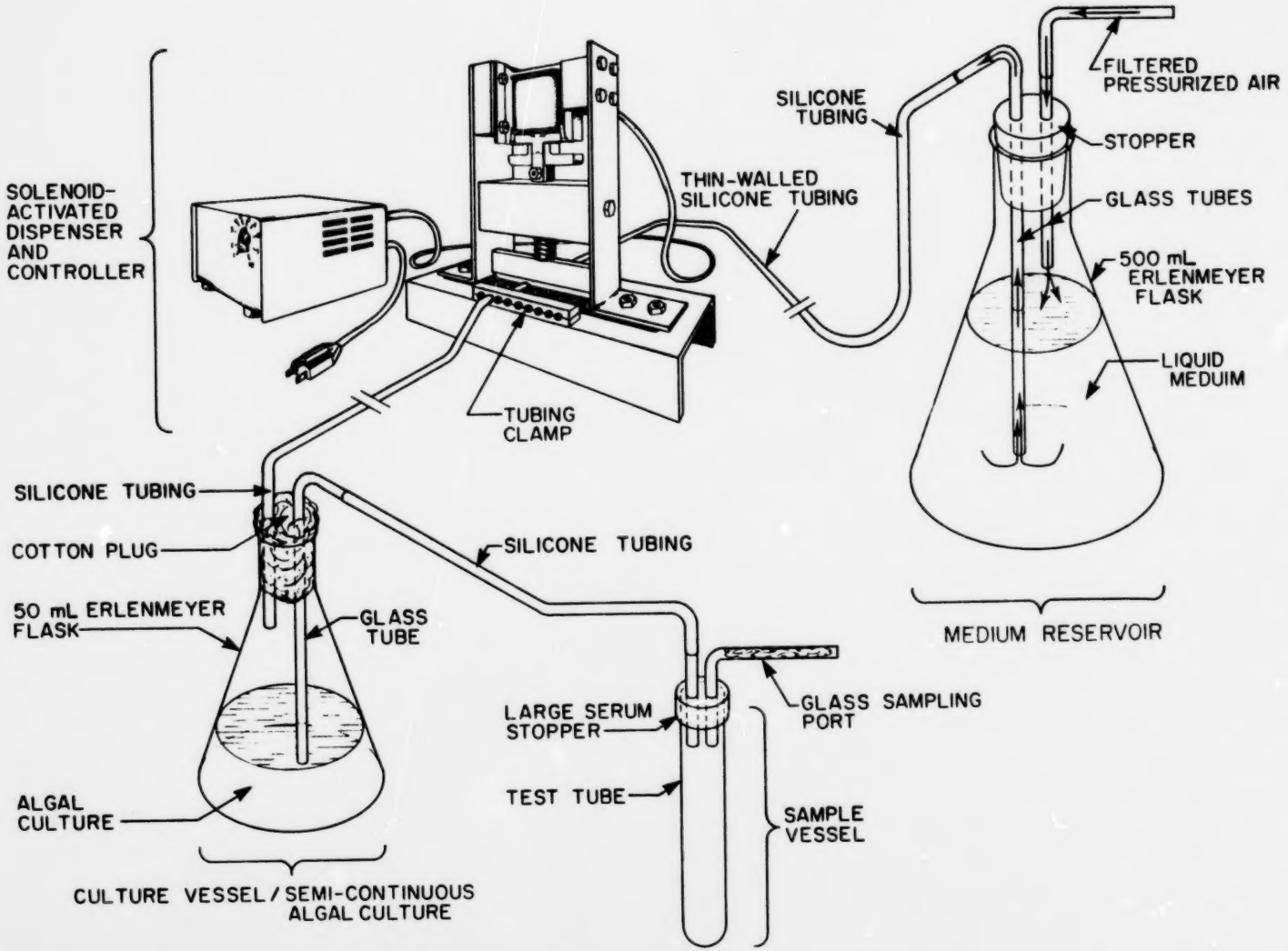

Figure 3. Diagram of the assembled components.